APPENDIX D

TRANSPORTATION RISKS ANALYSIS

This appendix includes (1) a general description of the RADTRAN4 Computer Model and a summary of the major assumptions used in estimating the doses for the cross-country (i.e., from reactor sites to PFSF) and regional (i.e., within the State of Utah) analyses; (2) a summary of NUREG-0170 (NRC 1977), which the staff used to compare the transportation results determined by RADTRAN4; (3) an analysis of the regional transportation risks for Utah; and (4) an analysis of the regional transportation risk for Wyoming.

D.1 Use of the RADTRAN4 Computer Model

As part of the analysis of potential impacts in this DEIS, a transportation risk assessment was performed using the INTERLINE routing code (see Appendix C) and the RADTRAN4 risk assessment code to determine the transportation impacts associated with the shipment by rail of commercial SNF inside certified shipping casks. The INTERLINE computer code model was used to select rail routes and analyze the transportation scenarios (Johnson, et al. 1993). The selected routes to Skull Valley, Utah, and Wyoming are illustrated in Chapters 2 and 7, respectively, of this DEIS.

This section describes the RADTRAN4 computer code and explains how it was used in the assessment of potential impacts. This section also discusses the shipment of SNF and its impact on the general public and on transportation workers. Both routine (i.e., non-accident) conditions and accident scenarios are included in the discussion, which has been taken from information contained in DOE (1998).

D.1.1 The RADTRAN4 Model

The RADTRAN4 calculations for generating the routine dose to the public are based on expressing the dose rate as a function of distance from a point source (Neuhauser and Kanipe 1993). Associated with the calculation of the routine doses for each exposed population group are parameters such as the radiation field strength, source-receptor distance, duration of exposure, vehicular speed, traffic density, and route characteristics (such as population density). The RADTRAN4 manual contains derivations of the equations and descriptions of these parameters (Neuhauser and Kanipe 1993).

The RADTRAN4 code calculates the dose to the public in an area that runs along the rail line and extends perpendicular from both sides of the track to a distance from 30 m to 800 m (98 ft to 0.5 mile). Added to this computed dose are the collective doses for persons that share the transportation route (e.g., oncoming passenger trains passing on parallel tracks). The dose (in mrem) received by each person in that area is a function of the dose rate (in mrem/hr) at 1 m from the cask surface, the distance that person is from the track, and the speed of the train as it passes by. The RADTRAN4 manual contains the derivations of the equations and descriptions of the parameters used in the code (Neuhauser and Kanipe 1993).

The radiation field that surrounds the cask decreases markedly as the distance from the cask increases. At distances from 30 m to 800 m (98 ft to 0.5 mile), the cask will appear almost like a point source and therefore, the dose rate will decrease as the square of the distance from the cask. Figure D.1 illustrates the approximate dose rate as a function of distance from a cask that reads 0.13 mSv/hr (13 mrem/hr) at 1 m (3 ft) from its surface, assuming the radiation field exists in a vacuum (e.g., there would be no buildup nor attenuation of the gamma rays in air).

Note that to estimate the dose received by a person at a specific distance from the track, the dose rate at that distance would have to be multiplied by the time the person is exposed. In general, this time is expected to be only a few minutes as the train passes by, and is a function of the train speed. Given the population density along various parts of the route, RADTRAN4 integrates the exposure of each person and sums them over the distance that person is from the rail line. The collective risk to the population along a specific route is determined by identifying the origin and destination of the SNF shipment, determining a rail route between the two points and identifying the population density along that route, based on 1990 census data. The population density is one of the input parameters to RADTRAN4 as described in the following section.

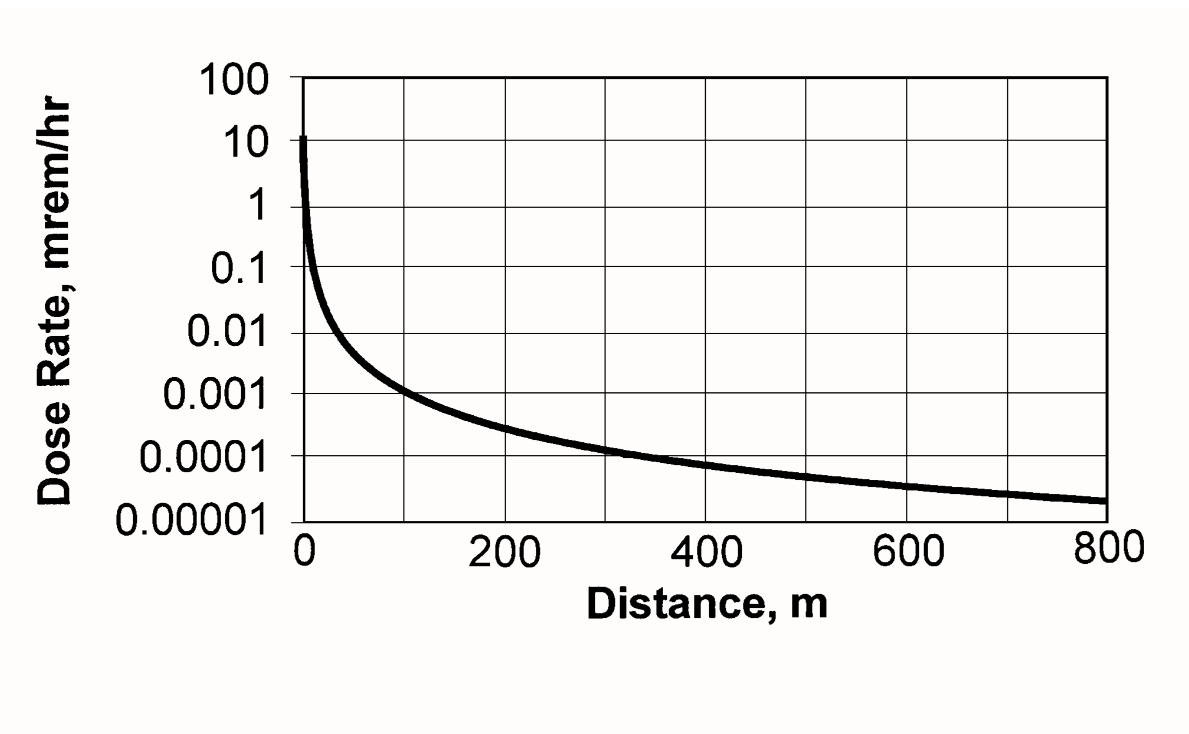

Figure D.1. Estimated dose rate as a function of distance from a cask reading 0.13 mSv/hr (13 mrem/hr) at 1 m (3 ft) from its surface.

D.1.2 Populations at Risk

For routine transportation, the RADTRAN4 computer code considers all major groups of potentially exposed persons. The RADTRAN4 calculations of risk for routine rail transportation include exposures of the following population groups:

- *Persons along the Route (Off-Link Population)*. Collective doses are calculated for all persons living or working within 0.8 km (0.5 miles) on each side of the transportation route. The total number of persons within a 1.6-km (1-mile) corridor is calculated separately for each route considered in the assessment.
- *Persons sharing the Route (On-Link Population)*. Collective doses are calculated for persons in all vehicles sharing the transportation route. This group includes persons traveling in the same or the opposite direction as the shipment, as well as persons in the vehicles passing the shipment.
- *Persons at Stops.* Collective doses are normally calculated for people who may be exposed while a shipment is stopped en route. The distance of each route analyzed for the regional transportation analysis was relatively short [i.e., approximately 400 km (250 miles)]; therefore, no rail stops were assumed. For the cross-country analysis two stops were assumed.
- *Crew Members.* Collective doses are calculated for rail crew members. It is assumed that each train carries two crew members in the locomotive.

The doses calculated by RADTRAN4 for the first three population groups are added to yield the collective dose to the public. The dose calculated for the fourth group represents the dose to workers (in this case the train crew).

In the RADTRAN4 calculations performed for this DEIS, three population density zones—rural, suburban, and urban—were used to compute the risk between the origin-and-destination pairs of every rail route which ended at either the PFSF site in Utah or the candidate site in Wyoming. The fractions of travel in each zone were determined by using the INTERLINE (rail) routing model (Johnson, et. al. 1993) as described in Appendix C of this DEIS. The routing model identified the specific population densities in each zone along each route based on the 1990 census data. Population density information in each of the three population density zones is based on an aggregation of the twelve population density zones provided in the INTERLINE output and is compatible with the RADTRAN4 code.

D.1.3 Risks During Routine Transportation

The results of the RADTRAN4 computer runs are displayed in Chapters 5 and 7 of this DEIS for the cross-country analysis and a brief summary of the regional transportation analysis is also included. Sections D.3 and D.4 in this appendix present the results of the regional transportation analysis. The output includes dose calculations for the public and the workers. These dose calculations have been converted into LCFs by the use of appropriate conversion factors. Numerical values for doses and LCFs appear in Chapters 5 and 7 of this DEIS as well as Sections D.3 and D.4 in this appendix.

D.1.4 Risks During Transfer at an Intermodal Transfer Facility

If the transport of SNF to the proposed PFSF occurs totally by rail (as would be the case if the new Skunk Ridge rail siding and rail line is constructed; see Chapter 2 of this DEIS), then any doses during railcar switching or railyard operations would be covered by the RADTRAN4 calculation. However, if the SNF shipping casks are transferred from railcars onto heavy-haul tractor/trailers (as would be the case if an ITF is constructed near Timpie, Utah; see Chapter 2 of this DEIS), then additional dose calculations apply. This subsection describes such calculations.

Timpie, Utah, is the assumed location on the Union Pacific rail line at which the intermodal transfer of casks from rail to tractor/trailer would take place. A new rail siding and cask handling equipment would be available at the Timpie ITF. The transfer activities that are expected to take place include radiation monitoring during the transfer, release of the shipping canister tiedowns from the railcar, hoisting the cask off of the railcar with a crane and moving it to a heavy-haul trailer, and re-securing the cask to the trailer.

At Timpie, the crew is assumed to consist of four handlers and a spotter, two inspectors, a crane operator and a health physicist. The handlers would attach ropes to the ends of the cask after it is released from the railcar and help guide it into a saddle on the trailer. The spotter would give directions to the crane operator and the handlers. The inspectors would ensure that all written operating procedures are followed. The health physicist would monitor the movement and check the cask surface.

An equation for estimating the dose received by those who interact with the SNF canister during the transportation transfer link is built into the RADTRAN4 code; it was described by Neuhauser and Weiner (1992) who applied it to the process of intermodal transfer of SNF shipping casks from a ship to a truck. The equation is as follows:

$$D = [(K \bullet DR \bullet PPS)/r] \bullet [T_H \bullet PPH \bullet N_H \bullet SPY] \qquad \text{Eqn. D.1}$$

where,

D	=	dose in person-mrem
K	=	line source coefficient = $(1+d_{eff}/2)$
d_{eff}	=	the effective shipping cask dimension, in meters [= 4.68 m (15.4 ft) for this calculation]
DR	=	dose rate in mrem/hr at 1 m from the shipping cask surface [= 0.13 Sv/h (13 mrem/h)] for this calculation
PPS	=	shipping casks per shipment (= 4 for this calculation)
T_H	=	exposure time, in hours
PPH	=	number of staff personnel
N_H	=	number of handlings per shipment
SPY	=	number of shipments (= 1 for this calculation), and
r	=	distance of handler from the source, in meters

Each of the four handlers would be expected to spend an average of 15 minutes at a distance of approximately 1 m (3 ft) from the cask before and/or during the transfer of each cask. The health physicist would be expected to average about 5 minutes also at a distance of 1 m (3 ft) from the cask. Each inspector would be expected to spend around 5 minutes within 2 m (6.6 ft) of the cask. A spotter would be expected to remain about 2 m (6.6 ft) away from the cask for a period of 15 minutes. The crane operator may spend 30 minutes in his cab while handling each cask; his cab would be located about 6 m (20 ft) from the cask.

Apart from the time these team members would be physically helping with the cask transfer, they are expected to retreat to an area some distance from the cask where the dose rate is negligible. As the team gets more experienced in the transfer operations, it would be expected that the dose rate received by the various intermodal transfer personnel would be reduced from what is calculated below using Eqn. D.1.

Table D.1 shows the estimated doses to the handlers, the spotter, the health physicist, crane operator, and the inspector associated with the unloading of four casks from a single train. The last column in the table indicates the estimated doses for all 50 trains expected in a 1-year period. For comparison, the allowable annual occupational whole-body dose for any one person in restricted-access areas, as cited in 10 CFR 20.1202(1)(i), is 50 mSv (5,000 mrem).

Table D.1. Estimated doses to intermodal transfer personnel in a one-year period

Personnel	Number of people	Distance from source [meters (ft)]	Exposure time (hours)	Dose per train, person-mSv, (person-mrem)	Dose per year, person-mSv, (person-mrem)
Handlers	4	1 (3)	0.25	1.74 (174)	87.0 (8,700)
Spotter	1	2 (6)	0.25	0.22 (22)	11.0 (1,100)
Inspectors	2	2 (6)	0.083	0.14 (14)	7.0 (700)
Health physicist	1	1 (3)	0.083	0.14 (14)	7.0 (700)
Crane operator	1	6 (18)	0.5	0.14 (14)	7.0 (700)
Total				2.38 (238)	119 (11,900)

D.1.5 Risks During Accidents

RADTRAN4 also contains equations to compute the doses to the public in the event of an accident that releases radioactive materials to the environment. One method used to characterize the potential severity of transportation-related accidents is described in an NRC report (NUREG-0170). This method is used by the RADTRAN4 program to identify severity categories and develop a probability-based analysis of accidents involving radioactive material shipping canisters. The RADTRAN4 program has the flexibility to divide the spectrum of transportation accidents into a number of categories. The analysis carried out for this DEIS used six categories as discussed in Table D.2 and as used in NRC (1987).

The scheme for accident severity is designed to take into account all credible transportation-related accidents, which can range from accidents with low probability but high consequences to those with high probability but low consequences.

Table D.2. Accident severity categories used in the analysis

RADTRAN4 severity category	Description
Severity category 1	Conditions do not exceed those for a Type A shipping cask; no release of contents
Severity category 2	Conditions equal those for Type B shipping cask certification tests; no release of contents
Severity category 3	Seal damage creates leak path, but fuel undamaged; only CRUD[a] could be expelled from the canister
Severity category 4	Impact damage great enough to cause damage to spent fuel; fuel particulates and fission gases may be released
Severity category 5	Impact damage to seals plus fire severe enough to cause thermal burst with release of fission gases, volatiles, and particulates
Severity category 6	Severe impact damage plus fire severe enough to cause fuel oxidation with release of greater amounts of fuel particulates than category 5.

[a]CRUD (Chalk River Unidentified Deposits) consists of corrosion products deposited on the fuel cladding during reactor operation. Loosely adhered CRUD is observed on power reactor spent fuel.

Source: Taken from "Environmental Assessment of Urgent-Relief Acceptance of Foreign Research Reactor Spent Nuclear Fuel," DOE/EA-0912 (April 1994).

Each severity category represents a set of accident scenarios defined by a combination of mechanical and thermal forces. A conditional probability of occurrence (i.e., the probability that if an accident occurs, it is of a particular severity) is assigned to each category. The fractional occurrences for accidents by the accident severity category and the population density zones (i.e., rural, suburban, and urban) are shown in Table D.3 and were taken from NRC (1987).

Table D.3. Fraction of accident occurrences

Accident severity category	Location		
	Rural	Suburban	Urban
1	9.94×10^{-1}	9.94×10^{-1}	9.94×10^{-1}
2	2.02×10^{-3}	2.02×10^{-3}	2.02×10^{-3}
3	2.72×10^{-3}	2.72×10^{-3}	2.72×10^{-3}
4	5.55×10^{-4}	5.55×10^{-4}	5.55×10^{-4}
5	6.14×10^{-4}	6.14×10^{-4}	6.14×10^{-4}
6	1.25×10^{-4}	1.25×10^{-4}	1.25×10^{-4}

Category 1 accidents is the least severe but the most occur most frequently. Category 6 accidents are very severe but very infrequent. Each population density zone was given the same distribution of accident frequencies for specific accident categories since information on the variation of frequency as a function of population density zones was not available.

Category 6 represents the most severe accident scenarios, which would result in the largest releases of radioactive material. Accidents of this severity are very rare, occurring approximately 1 in every 10,000 rail accidents involving a radioactive waste shipment. On the basis of national accident statistics (Saricks and Kvitek 1994) for every 1.6 km (1 mile) of a loaded shipment, the probability of an accident of this severity is 1×10^{-12} for shipment by rail. For this DEIS in which the estimated shipping distance in the entire 40-year campaign is on the order of 16 million kilometers (10 million miles) (see Chapter 5 of this DEIS), no accident of such severity is expected to occur.

Radiological consequences of accidents are calculated by assigning shipping cask release fractions to each accident severity category. The release fraction is defined as the fraction of the radioactive material in the cask that could be released from that cask during an accident of a certain severity. Release fractions take into account all mechanisms necessary to create release of radioactive material from a damaged shipping cask to the environment. Release fractions vary according to the shipping cask type and the physical form of the waste.

In the case of SNF, there would be some solids, gases, and volatile materials that could be released should the cask seal be breached in a severe accident. Some of the radioactive gases that are generated in the fuel pellets, diffuse and collect in the gas plenum of each fuel rod and would be released to the cask cavity from each fuel rod that is ruptured in an accident. Volatile gases generally require heat to cause them to diffuse into the gas plenum and remain in a gaseous form. Solids would come from fuel pellets, some of which could be crushed, producing fines, a powder-like material. The fines would have to escape their fuel tubes, some of which are likely to be ruptured in a severe accident, and be distributed within the cask cavity. Once this powdery material and the gases are free to move about the cask cavity, if the cask is breached, some fraction of that material can be released from the cask.

The most likely breach in a shipping cask would be caused by a gasket that failed in the accident, opening a small vent between the cavity and the environment. Table D.4 identifies the release fractions for solid, powder-like particles, gases and volatile materials that are assumed to be released as a function of severity of the accident. These release fractions are based on NRC (1987).

Accident consequences and numerical risks are presented in Chapter 5 of this DEIS and in Sections D.7 and D.8 in this appendix.

D.2 Summary of NUREG-0170

NUREG-0170 (NRC 1977) examined impacts from transporting all licensed material by land, air, and sea transport modes under both incident-free and accident conditions. One of the 25 radioactive materials examined by NUREG-0170 was SNF. For SNF shipments that occur without accidents (incident-free transport), radiation doses were estimated for members of the general public who would be exposed to radiation, for example, because they lived near the shipment route, and also for workers (e.g., crew, handlers, inspectors). Release of radioactive materials from SNF to the

Table D.4. Assumed release fractions from a spent fuel cask

Accident severity category	Material		
	Particulates	Volatiles	Gases
1	0	0	0
2	6.00×10^{-8}	6.00×10^{-6}	9.90×10^{-3}
3	2.00×10^{-7}	2.00×10^{-5}	3.30×10^{-2}
4	2.00×10^{-6}	2.00×10^{-4}	3.30×10^{-1}
5	2.00×10^{-6}	2.00×10^{-4}	3.90×10^{-1}
6	2.00×10^{-5}	2.00×10^{-3}	6.30×10^{-1}

environment as a result of transportation accidents, the probability of these releases, and the LCFs that such releases might cause were also estimated. For NUREG-0170, SNF transport risks were estimated for shipment by truck and by train over a generic highway and a generic rail route.

NUREG-0170 contains an assessment of SNF shipment risk using the 1975 level of shipments, and a projection of risks for 1985, based on the assumption of a reprocessing fuel cycle. Sandia National Laboratories conducted the risk assessment for NRC, and developed the original RADTRAN (RADTRAN 1) radioactive material transport risk code, to perform the related dose calculations.

Considering the information developed and received during development of NUREG-0170, and the safety record associated with the transportation of radioactive material, the Commission determined that the regulations then in place (which are very similar to today's regulations) were adequate to protect the public against unreasonable risk from the transport of radioactive materials, and that no immediate changes in the regulations were needed to improve safety (46 FR 21619).

For accidents, NUREG-0170 considered two release models, Model I and Model II. For calculations of radiological consequences that might be caused by accidents, accidents were divided into eight categories (Categories I through VIII) of increasing severity. Because "little information relating the response of shipping casks to accident environments" (NRC 1977) was available in 1975 for SNF and other highly radioactive materials shipped in Type B casks; release of radioactivity as a result of accidents was examined using two release models. Model I, assumed that "zero release occurs up to the regulatory test level and that the packaging fails catastrophically in all environments that exceed that level" (NRC 1977). Each radionuclide was assumed to be released to the environment by this "catastrophic" failure; thus, Model I assumed that the radioactive release would take place whenever a Type B shipping cask was subjected to mechanical or thermal loads in excess of the mechanical and thermal loads encountered during shipping cask certification tests (10 CFR 71.73). Because the Model I cask release behavior was considered to be unrealistic (shipping casks yield gradually, they do not fail catastrophically), a second release model (Model II) was formulated. In Model II, for accidents that exceed the regulatory test level, release fractions increased more gradually with accident severity eventually becoming equal to Model I for the last three accident severity levels.

D.3 Regional Transportation Risks Near Skull Valley, Utah

Exposures to members of the public and to occupational personnel as a result of transporting SNF casks have been the subject of several previous investigations as discussed above. Because that previous work was based on regulatory criteria for radiation levels at 1 m (3 ft) from the surface of transportation casks, the previous work applies to the transportation of SNF from utilities to the proposed PFSF in Skull Valley.

This section discusses the projected radiation dose from transporting the SNF casks to the proposed PFSF in Skull Valley using identified rail access routes and the average population densities along those routes. The results from the radiological transportation risk assessment include the radiological impacts to the general population, workers, and a hypothetical MEI with emphasis on the Salt Lake City and Skull Valley region. The results are also presented in terms of LCFs.

The transportation risk assessment was performed using the INTERLINE routing code and the RADTRAN4 risk assessment code to determine the cumulative transportation impacts in Utah and neighboring states associated with the transport of commercial SNF. The impacts considered were the human health effects associated with both normal transport (incident-free) and with potential accidents severe enough to release radioactive material.

Because of the size and weight of the SNF shipping casks included in the PFS application for a license, shipment by rail is the only viable cross-country transportation option. Therefore, the focus of the analysis below is on rail transportation.

D.3.1 Identification of Routes

The INTERLINE computer code model was used to select routes and analyze the transportation scenarios (see Appendix C of this DEIS). For the purpose of this analysis, it is assumed that all SNF transported to the proposed PFSF in Skull Valley, Utah, will be shipped by rail. While shipment of SNF by truck over highways is possible, the size of the proposed shipping cask system to be used for the proposed PFSF makes the use of rail transportation essential for the transport of SNF. Only when the shipments reach the northern end of Skull Valley would transport by truck (i.e., heavy-haul vehicle) for the remaining short distance become viable.

Currently, there is no direct rail access to the proposed PFSF in Skull Valley. This analysis assumes that a new 51-km (32-mile) rail line would be constructed from Skunk Ridge (located northeast of the Low passing siding) to the proposed PFSF site (see Chapter 2 of this DEIS). The Union Pacific Railroad owns the existing rail line at Skunk Ridge. Rail access routes and route lengths were selected as discussed in Appendix C of this DEIS.

D.3.2 Radiological Impacts

The RADTRAN4 computer code (Neuhauser 1984, 1992) was used to model both the incident-free radiological exposure and the consequences of radiological releases due to severe accidents. The incident-free risks are dependent on the radiation dose rate from the shipment, the number of shipments, the shipping cask dimensions, the route distance, the vehicle velocity, and the population densities along the travel routes. The accident risks are dependent on the radiological inventory, the severity of the accident, the probability of occurrence for each accident category, and the amount of inventory released, aerosolized, and inhaled, as well as the dispersibility of the waste form.

The proposed PFSF would be expected to receive approximately 200 casks per year, or about four casks per week. Although the shipments are expected to average four casks per train into Utah, each train can be expected to handle anywhere from one to six casks. If the proposed PFSF receives about 200 casks per year, each averaging four casks per train, then on the average, 50 trains per year will converge on Utah.

To examine the radiological impacts on the public and the crews used to ship and handle the casks, RADTRAN4 was used. The calculation included the impact on the public assuming that all 200 casks are shipped, one cask per train. This assumption maximizes the radiological impact to the public and conservatively estimates the dose from multiple casks per train. That is, cask-carrying railcars may be separated by buffer cars and thus may become more of a separate radiation source to the public. However, because adding more casks to a single train increases the distance between the additional casks and the rail crew, and places more shielding (in the form of closer casks) between the additional casks and the crew, the crew would not be expected to receive much more radiation from multiple-cask trains than they would from single-cask trains. Therefore, the dose received by the rail crew was modeled assuming there would be 50 rail shipments consisting of four casks each.

Incident-free radiological exposure was determined by calculating a total body dose for the transport crew and the general population from the radiation dose rate at 1 m (3 ft) from the shipping canister surface. Both point-source and line-source approximations were used based upon the distance between the exposed individuals and the radiation source. Each cask is assumed to contain 24 PWR fuel assemblies that have been cooled for five years. Because of the specific radionuclide content of PWR fuel assemblies and the number of assemblies inside each canister, PWR assemblies would produce a greater dose than BWR assemblies in the event of an accident that breaches the canister. Each cask was assumed to have a dose rate of 0.13 mSv/hr (13 mrem/hr) at a distance of 1 m (3 ft) from the cask surface which is equivalent to the regulatory limit of 0.10 mSv/hr (10 mrem/hr) at 2 m (6 ft). The source term was assumed to consist entirely of gamma radiation for calculation of the incident-free dose.

The maximum exposed individual (MEI) is defined as an unshielded individual that is hypothetically positioned 30 m (98 ft) from the highway or railroad track. The conveyance transporting the radioactive material considered in the analysis is modeled as passing by the MEI at a speed of 24 km/hr (15 mph). This MEI is affected by the defined package dose rate and the number of shipments that pass his or her location over the time period under consideration. It is assumed that the MEI is present for all SNF shipments made over the time period considered.

The dispersibility category is used to characterize the relative dispersibility of the SNF inventory based upon the chemical and physical properties of the SNF transported. RADTRAN4 uses the dispersibility category to determine the fractions of the total inventory that are aerosolized and respirable. RADTRAN4 contains default values for aerosolized and respirable fractions of the total inventory based on the assignment of dispersibility category. The user assigns a dispersibility category to each material and chooses release fractions based on the type of shipping cask as a function of accident severity (see Table D.4). For these RADTRAN4 calculations, the release fractions in Table D.4 already account for the aerosolized and respirable fractions.

Accident risks consider LCFs due to hypothetical accidents. The accident risk (expected value of dose from accidents) is the summation of the products of estimated dose for each accident-severity category and the associated probability of occurrence for that category.

The radiological health effects are presented in this section assuming the radioactive inventory of the cask is as shown in Table D.5. All fuel shipped to the site was assumed to have an average burnup of 40,000 MWD/MTU and be cooled for five years. Activation products, actinides, and fission products were all identified and those elements whose activities exceeded about 1 percent of the total are listed in Table D.5.

Table D.5. Radionuclide inventory for the proposed SNF shipments

Isotope	Ci/shipping canister— 5 years cooled	Ci/shipping canister— 20 years cooled	Physical/chemical group	Dispersibility category
Cobalt-60	5.23×10^{2}	7.27×10^{1}	particulates	6
Krypton-85	9.07×10^{4}	3.43×10^{4}	gas	10
Strontium-90	8.86×10^{5}	6.19×10^{5}	volatile	7
Ruthenium-106	1.84×10^{5}	6.07×10^{0}	volatile	7
Cesium-134	4.20×10^{5}	2.71×10^{3}	volatile	7
Cesium-137	1.23×10^{6}	8.66×10^{5}	volatile	7
Promethium-147	4.06×10^{5}	7.70×10^{3}	particulates	2
Samarium-151	5.35×10^{3}	4.78×10^{3}	particulates	2
Europium-154	8.76×10^{4}	2.62×10^{4}	particulates	2
Plutonium-238	4.37×10^{4}	3.89×10^{4}	particulates	2
Plutonium-239	4.34×10^{3}	4.34×10^{3}	particulates	2
Plutonium-240	6.19×10^{3}	6.22×10^{3}	particulates	2
Plutonium-241	1.25×10^{6}	6.10×10^{5}	particulates	2
Americium-241	1.34×10^{4}	3.43×10^{4}	particulates	2
Americium-243	2.35×10^{2}	2.38×10^{2}	particulates	2
Curium-242	4.54×10^{2}	2.03×10^{2}	particulates	2
Curium-244	2.74×10^{4}	1.54×10^{4}	particulates	2
Total activity	4.65×10^{6}	2.27×10^{6}		

D.3.2.1 Shipment Modes and Destinations

Rail shipments through Skull Valley. Although shipments are expected to be made to the proposed PFSF by rail, no rail connection currently exists at the main Union Pacific trackage that passes north of the Reservation. One shipping scenario is that a rail line would be extended from a junction at Skunk Ridge to the proposed PFSF. Once the new rail line is constructed, the expected operation of the transportation system would be to bring the cask-carrying railcars in by the Union Pacific system to the new Skunk Ridge siding and couple the railcars (with the SNF shipping casks) to dedicated locomotives that would haul the casks to the proposed PFSF. The Union Pacific engineers would park the cask cars and uncouple them from the locomotive on the rail siding. The PFSF's rail engineers would take several minutes to couple their locomotive to the cask cars, inspect the cars for any defects, test brake line pressure, and travel down the 51-km (32-mile) line to the proposed PFSF.

The dose rate of the PFSF's rail engineers would be approximately the same as it was for the Union Pacific engineers.

There are five possible rail routes that could bring SNF shipping canisters into the Skunk Ridge siding area. As discussed in Appendix C, they include as starting points Black Rock, UT, Carlin, NV, Granger, WY, Green River, UT, and Pocatello, ID. Because it is difficult to tell at this time how much SNF each reactor would transfer to the proposed PFSF and which routes they might use, it was assumed that all 200 cask shipments each year move along each of the routes that have been identified. This assumption provides a conservative, upper-bound result for the exposure of the population along each route. Because each route is expected to carry some shipments, the actual exposures should be considerably less than the exposures computed along any of the routes shown. The results of the RADTRAN4 computer runs for these shipments are discussed below. The exposure data are presented in Table D.6.

Truck shipments through Skull Valley. If the new rail line is not built from Skunk Ridge, the Timpie siding is the assumed location on the Union Pacific rail line at which the ITF would be built. The ITF is the facility at which the transfer facility of SNF shipping casks from rail to truck would take place. The casks would have to be moved the last 41 km (26 miles) to the proposed SNF by truck. A rail siding and cask handling equipment will be available at the ITF site. It is anticipated that four casks would come to the ITF each week, 50 times a year. One of the casks would be off-loaded from its railcar and would be placed on a heavy-haul trailer (see Chapter 2 of this DEIS). The other three casks would be left on the railcars stopped on the rail siding.

The cask transfer activities that are expected to take place at the ITF include radiation monitoring during the cask transfer, release of the shipping canister tiedowns from the railcar, hoisting the cask off of the railcar with a crane and moving it to the heavy-haul trailer, and re-securing the cask to the trailer. Shipments would be made only during the daylight hours.

At the ITF, the crew is assumed to consist of four handlers and a spotter, two inspectors, a crane operator and a health physicist. The handlers would attach ropes to the ends of the cask after it is released from the railcar and help guide it into a tie-down cradle on the low-boy trailer or to the temporary storage location. The spotter would give directions to the crane operator and the handlers. The inspectors would ensure that all written procedures are followed. The health physicist would monitor the movement and check the cask surfaces. The equation for estimating the dose received by the ITF crew is built into the RADTRAN4 code and has been used to estimate the dose received by handlers and inspectors in an intermodal transfer of SNF shipping casks (Neuhauser and Weiner 1992). Using similar exposure times, the total dose received by the ITF staff is 0.119 person-Sv/yr (11.9 person-rem/yr), or 2.38 person-Sv (238 person-rem) over the entire 20-year campaign of shipping SNF to Skull Valley.

Each truck shipment to the PFSF would be accompanied by escorts: one in front and one at the rear of the heavy-haul tractor/trailer in accordance with Utah Department of Transportation Regulations

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Table D.6. Summary of doses shipped to the proposed PFSF by rail via the proposed Skunk Ridge siding

	Annual dose, 200 casks per year				20 year life campaign[a]			
To PFSF from:	**Crew dose, [person-Sv (person-rem)]**	**Pop. dose, [person-Sv (person-rem)]**	**MEI, [Sv (rem)]**	**Accident pop. dose[b] [person-Sv (person-rem)]**	**Crew dose, [person-Sv (person-rem)]**	**Pop. dose, [person-Sv (person-rem)]**	**MEI, [Sv (rem)]**	**Accident pop. dose[b] [person-Sv (person-rem)]**
Black Rock, UT	0.00412 (0.412)	0.00091 (0.091)	1.11×10^{-6} (1.11×10^{-4})	0.000188 (0.0188)	0.0824 (8.24)	0.0182 (1.82)	2.22×10^{-5} (2.22×10^{-3})	0.00376 (0.376)
Carlin, NV	0.0041 (0.41)	0.000624 (0.0624)	1.11×10^{-6} (1.11×10^{-4})	0.000113 (0.0113)	0.0820 (8.20	0.0125 (1.25)	2.22×10^{-5} (2.22×10^{-3})	0.00226 (0.226)
Granger, WY	0.00590 (0.590)	0.00520 (0.520)	1.11×10^{-6} (1.11×10^{-4})	0.00237 (0.237)	0.118 (11.8)	0.104 (10.4)	2.22×10^{-5} (2.22×10^{-3})	0.0474 (4.74)
Green River, UT	0.00594 (0.594)	0.00619 (0.619)	1.11×10^{-6} (1.11×10^{-4})	0.00222 (0.222)	0.119 (11.9)	0.124 (12.4)	2.22×10^{-5} (2.22×10^{-3})	0.0444 (4.44)
Pocatello, ID	0.00588 (0.588)	0.00564 (0.564)	1.11×10^{-6} (1.11×10^{-4})	0.00233 (0.233)	0.118 (11.8)	0.113 (11.3)	2.22×10^{-5} (2.22×10^{-3})	0.04665 (4.665)

[a]Assumes all 4,000 casks shipped over the entire campaign are transferred over each of the five rail segments identified.
[b]Upper bound and assumes that all four casks all release the same amount of activity in an accident. A more likely scenario is for only one cask to release activity in a severe accident, in which case the dose received by the population in an accident would be lower by a factor of approximately 3.58.

for Legal and Permitted Vehicles, Section 600. The heavy-haul tractor/trailer would be expected to travel at a speed of about 32 km/hr (20 mph) over the 41 km (26-mile) road to the PFSF. The trip would take approximately 1.3 hours. It is anticipated that the two escort vehicles will travel up to 300 m (1,000 ft) ahead of and behind the heavy-haul tractor/trailer to warn travelers of the slow moving truck. Once unloaded, the heavy-haul tractor/trailer and escorts can return to the ITF and pick up the next cask.

Assuming there would be one driver in the tractor/trailer and the dose rate in the cab is at the maximum U.S. DOT limit of 0.02 Sv/hr (2 mrem/hr), the dose to the driver would not exceed 0.026 mSv (2.6 mrem) for each trip. In fact, with a single tractor/trailer designed to make this drive on a continuing basis, it would be easy to provide some small amount of additional radiation shielding for the driver, thereby reducing the driver's dose to a fraction of this amount. The PFSF driver(s) would make 200 such shipments each year. The total accumulated dose to the drivers of the tractor/trailer would not exceed:

(200 shipments/yr) • [0.026 mSv ((2.6 mrem)/shipment] = 5.2 mSv/yr (520 mrem/yr).

This translates to a maximum cumulative dose of 0.104 person-Sv (10.4 person-rem) for the 20-year campaign.

Escorts. If the escorts drive an average of 240 m (800 ft) in front of and behind the shipping cask on the heavy-haul tractor/trailer, the dose rate in their vehicles, assuming no intermediate shielding such as the body of the vehicles they are riding in or the cab of the heavy haul tractor/trailer, should not exceed 2×10^{-6} mSv/hr (0.0002 mrem/hr) (see Figure D.1). If there are two escorts in each vehicle, the four escorts would receive:

(200 shipments/yr) • (4 persons/shipment) • [2×10^{-6} mSv (0.0002 mrem/hr) per person]
• (1.5 hr/shipment) = 0.0024 person-mSv/yr (0.24 person-mrem/yr).

This translates to a maximum cumulative dose of 0.048 person-mSv (4.8 person-mrem) to the escorts for the 20-year campaign.

The results of the RADTRAN4 computer runs for these intermodal shipments are discussed below, and the exposure data are presented in Tables D.7 and D.8.

D.3.2.2 Shipments to a Final Repository

The SNF would remain at the proposed PFSF for a number of years, after which it would be removed and transported to the final repository. It is assumed that the repository will be at Yucca Mountain and the path that will be followed will be from the proposed PFSF to the Nevada-Utah border and onward to the repository. This section examines the radiological risk of transporting all 4,000 SNF canisters from the PFSF to the Nevada-Utah border.

For this case, it is assumed that the fuel in the canisters would have been cooled at least 20 years and that the shipping casks designed to bring the canisters to the PFSF would be used to ship them to the repository. This will (1) avoid the cost of designing, certifying, and fabricating new casks, (2) minimize some potential handling activities and (3) have the additional benefit of reducing the dose rate from the cask because of the decay of many of the isotopes that make up the source term.

Table D.7. Summary of annual doses shipped to the PFSF via the Timpie siding

To PFSF via Timpie, from:	Rail, annual dose[c]			Truck, annual dose		Total annual dose	
	Crew dose, [person-Sv (person-rem)]	Pop. dose, [person-Sv (person-rem)]	Annual crew transfer dose, [person-Sv (person-rem)]	Crew dose[a], [person-Sv (person-rem)]	Pop. dose[b], [person-Sv (person-rem)]	Crew dose, [person-Sv (person-rem)]	Pop. dose, [person-Sv (person-rem)]
Black Rock, UT	0.00398 (0.398)	0.00086 (0.086)	0.119 (11.9)	0.00524 (0.524)	0.00254 (0.254)	0.1282 (12.82)	0.0034 (0.34)
Carlin, NV	0.00408 (0.408)	0.00062 (0.062)	0.119 (11.9)	0.00524 (0.524)	0.00254 (0.254)	0.1283 (12.83)	0.0032 (0.32)
Granger, WY	0.00576 (0.576)	0.00515 (0.515)	0.119 (11.9)	0.00524 (0.524)	0.00254 (0.254)	0.1300 (13.00)	0.0077 (0.77)
Green River, UT	0.00580 (0.580)	0.00580 (0.580)	0.119 (11.9)	0.00524 (0.524)	0.00254 (0.254)	0.1300 (13.00)	0.0083 (0.83)
Pocatello, ID	0.00574 (0.574)	0.00556 (0.556)	0.119 (11.9)	0.00524 (0.524)	0.00254 (0.254)	0.1300 (13.00)	0.0081 (0.81)

[a]Driver plus escorts.
[b]Essentially 100 percent of this population dose is received by persons who are on-link in cars passing the truck carrying the cask.
[c]Assumes all 200 casks are shipped annually.

Table D.8. Summary of 20-year campaign doses shipped to the PFSF via the ITF near Timpie

To PFSF via Timpie, from:	Rail, 20 year campaign[c] Crew dose, [person-Sv (person-rem)]	Rail, 20 year campaign[c] Pop. dose, [person-Sv (person-rem)]	Crew transfer dose, 20-year [person-Sv (person-rem)]	Truck, 20 year campaign Crew dose[a], [person-Sv (person-rem)]	Truck, 20 year campaign Pop. dose[b], [person-Sv (person-rem)]	Total dose, 20 year campaign Crew dose, [person-Sv (person-rem)]	Total dose, 20 year campaign Pop. dose, [person-Sv (person-rem)]
Black Rock, UT	0.0796 (7.96)	0.0172 (1.72)	2.38 (238)	0.105 (10.5)	0.0510 (5.10)	2.564 (256.4)	0.068 (6.8)
Carlin, NV	0.0816 (8.16)	0.0125 (1.25)	2.38 (238)	0.105 (10.5)	0.0510 (5.10)	2.566 (256.6)	0.063 (6.3)
Granger, WY	0.115 (11.5)	0.103 (10.3)	2.38 (238)	0.105 (10.5)	0.0510 (5.10)	2.600 (260.0)	0.154 (15.4)
Green River, UT	0.116 (11.6)	0.116 (11.6)	2.38 (238)	0.105 (10.5)	0.0510 (5.10)	2.601 (260.1)	0.167 (16.7)
Pocatello, ID	0.115 (11.5)	0.111 (11.1)	2.38 (238)	0.105 (10.5)	0.0510 (5.10)	2.600 (260.0)	0.162 (16.2)

[a]Driver plus escorts.
[b]Essentially 100 percent of this population dose is received by persons who are on-link in cars passing the truck carrying the cask.
[c]Assumes all 4,000 casks shipped over the entire campaign are transferred over each of the five rail segments identified.

Comparing the activity of 5-year-old fuel with 20-year-old fuel with the same burn-up, the most significant isotopes will be reduced by a factor of two. To a first approximation, the dose rate is assumed to be reduced by this same ratio, i.e., to 0.065 mrem/hr (6.5 mrem/hr) at a distance of 1 m (3 ft) from the cask surface. Using this as the external dose rate, the 4,000 shipments are assumed to be moved away from the PFSF at a rate of 200 casks per year for 20 years. The exposure data that results from RADTRAN4 runs on these shipments is given in Table D.9.

D.3.2.3 Dose Received by Public and Workers

Table D.6 summarizes the annual and the 20-year campaign radiation dose received by the crew and the public during the rail shipments from the five locations identified for the proposed PFSF in Skull Valley, assuming a new rail line is built from Skunk Ridge to the proposed PFSF. The lower exposure values received by the public when the shipments arrive via the Black Rock and Carlin locations reflect the low population densities around those rail lines compared to the higher population densities around the rail lines that reach the proposed PFSF from the Granger, Green River, and Pocatello locations.

At the ITF, the casks would be transferred to heavy-haul tractor/trailers and moved to the proposed PFSF. Table D.7 summarizes the annual dose that the crew of the general public would receive. Table D.8 identifies the dose received during a 20-year shipping campaign by the general public and workers, e.g., handlers and inspectors at the ITF, as well as the dose received by the heavy-haul driver(s) and the escorts. The doses received by the different segments of the population (e.g., the crews, including the cask transfer personnel at the ITF, and the population) are summed in the rightmost columns of Table D.8. It is apparent from a comparison of Tables D.6 and D.8 that the working crews, particularly those that are involved with the intermodal transfer at the ITF receive the largest potential dose. However, the dose received by the general population is also higher when the casks are shipped to the PFSF using heavy-haul tractor/trailers on Skull Valley Road and the ITF.

Table D.9 summarizes the radiation dose received by the rail crew and the public if all the casks are shipped away from the proposed PFSF to a permanent repository by rail to the Nevada-Utah border via the new Skunk Ridge junction. The exposures would be about half of those expected from incoming shipments. This is entirely the result of the isotopic decay while the SNF is in storage at the PFSF which in turn lowers the assumed dose rate at the outside of the shipping cask.

D.3.2.4 Radiological Consequences

Based upon the results of the RADTRAN4 computer runs shown in Table D.6, Table D.10 lists the risk of LCFs for shipments of SNF expected to result from radiation exposure during incident-free transportation and accidents assuming all the shipments come to the proposed PFSF in Skull Valley on each of the five possible routes. Based on the dose information shown in Table D.8, Table D.11 lists similar information for the intermodal shipments passing through the ITF near Timpie. As noted previously, each route provides a conservative estimate, since some shipments would come to the proposed PFSF on each of the routes, reducing the risk on any of the specific routes examined. Radiation doses to the population and rail crews were converted to estimates of LCFs using the upper limit risk coefficient suggested by the National Academy of Sciences (NAS) (ICRP 1991; NAS 1990).

Table D.9. Summary of doses from the outbound shipments from PFSF to a permanent repository as far as the Utah-Nevada border. Includes the shipment of 200 casks per year, each containing twenty-four 20-year cooled PWR fuel assemblies, and a dose rate of 0.065 mSv/hr (6.5 mrem/hr) at 1 m (3 ft) from the cask shipped from the PFSF by rail via the Skunk Ridge siding

	Annual dose, 200 casks per year[a]				20 year life campaign			
From PFSF to:	Crew dose, [person-Sv (person-rem)]	Pop. dose, [person-Sv (person-rem)]	MEI, [Sv (rem)]	Accident pop. dose [person-Sv (person-rem)]	Crew dose, [person-Sv (person-rem)]	Pop. dose, [person-Sv (person-rem)]	MEI, [Sv (rem)]	Accident pop. dose [person-Sv (person-rem)]
Utah-Nevada border	0.00218 (0.218)	0.0008 (0.08)	5.54×10^{-7} (5.54×10^{-5})	0.000223 (0.0223)	0.0436 (4.36)	0.0160 (1.60)	1.11×10^{-5} (1.11×10^{-3})	0.00446 (0.446)

Table D.10. Summary of the cumulative annual and 20-year campaign risks (as measured by latent cancer fatalities) for the shipment of spent nuclear fuel by rail via the Skunk Ridge siding to the proposed PFSF site in Skull Valley, Utah

	Risks (LCFs) from 1 year rail shipments			Risks (LCFs) from 20 years of rail shipments		
	Incident-free risk		Accident risk[a]	Incident-free risk		Accident risk[a]
To PFSF from:	Crew	Public	Public	Crew	Public	Public
Black Rock, UT	1.65×10^{-4}	4.55×10^{-5}	9.40×10^{-6}	3.30×10^{-3}	9.10×10^{-4}	1.88×10^{-4}
Carlin, NV	1.64×10^{-4}	3.12×10^{-5}	5.65×10^{-6}	3.28×10^{-3}	6.25×10^{-4}	1.13×10^{-4}
Granger, WY	2.36×10^{-4}	2.60×10^{-4}	1.19×10^{-4}	4.72×10^{-3}	5.20×10^{-3}	2.37×10^{-3}
Green River, UT	2.38×10^{-4}	3.10×10^{-4}	1.11×10^{-4}	4.76×10^{-3}	6.20×10^{-3}	2.22×10^{-3}
Pocatello, ID	2.35×10^{-4}	2.82×10^{-4}	1.17×10^{-4}	4.72×10^{-3}	5.65×10^{-3}	2.33×10^{-3}

[a]Upper bound and assumes that all four casks on a single train all release the same amount of activity in an accident. A more likely scenario is for only one cask to release activity in a severe accident, in which case the dose received by the population in an accident would be lower by a factor of approximately 3.58.

Table D.11. Summary of the cumulative 20-year campaign risks [as measured by latent cancer fatalities (LCFs)] for the intermodal shipment of spent nuclear fuel to the proposed PFSF site via the ITF near Timpie

To PFSF via Timpie, from:	Rail risk (LCFs) incident-free		Transfer risk (LCFs) incident-free	Truck risk (LCFs) incident-free		Total risk (LCFs) incident-free		Accident risk (LCFs)
	Crew	Public	Crew	Crew	Public	Crew	Public	Public
Black Rock, UT	3.18×10^{-3}	8.60×10^{-4}	0.0952	4.19×10^{-3}	2.54×10^{-3}	0.103	3.40×10^{-3}	1.89×10^{-4}
Carlin, NV	3.26×10^{-3}	6.25×10^{-4}	0.0952	4.19×10^{-3}	2.54×10^{-3}	0.103	3.15×10^{-3}	1.14×10^{-4}
Granger, WY	4.60×10^{-3}	5.15×10^{-3}	0.0952	4.19×10^{-3}	2.54×10^{-3}	0.104	7.70×10^{-3}	2.37×10^{-3}
Green River, UT	4.64×10^{-3}	5.80×10^{-3}	0.0952	4.19×10^{-3}	2.54×10^{-3}	0.104	8.35×10^{-3}	1.77×10^{-3}
Pocatello, ID	4.60×10^{-3}	5.55×10^{-3}	0.0952	4.19×10^{-3}	2.54×10^{-3}	0.104	8.10×10^{-3}	2.33×10^{-3}

The NAS report, commonly called the "BEIR V report," gives statistics on the number of cancer deaths expected to occur from a continuous exposure of 1 rem/year above background from age 18 until age 65. This value results in a risk factor of 4.0×10^{-6} LCFs per person-Sv (4.0×10^{-4} LCFs per person-rem) that is most applicable to occupational exposures. The BEIR V report also considers the number of cancer deaths expected to occur from a continuous lifetime exposure of 0.001 Sv/yr (0.1 rem/yr) above background which results in a risk factor of 5×10^{-6} LCFs per person-Sv (5.0×10^{-4} LCFs per person-rem) that is most applicable to exposures of the general public. Note that even though the assumed general public exposure is less than the assumed occupational exposure, the general public LCF risk factor is slightly higher. This is because the general public dose is assumed to occur over an entire lifetime as opposed to the occupational work period (e.g., 8-hr day shift) from age 18 until age 65. Both of these risk factors were used in this study depending upon whether the exposures were occupational or general population exposures. Assuming an average of four casks are shipped on each train, this assessment (summarized in Table D.11) indicates that the radiological risks of the rail shipments of SNF through Skunk Ridge are quite low. For the entire 20-year campaign, the number of LCFs statistically expected to occur from the calculated exposure data would not exceed 4.76×10^{-3} LCFs for the two-person crew or 6.20×10^{-3} LCFs for members of the public exposed during incident-free transportation if all the shipments came through the Green River, Utah, route. Table D.12 indicates that the incident-free risk associated with intermodal shipments, particularly to crew members, is higher than if the SNF shipping casks were transported entirely by rail.

The results of the analysis indicate that there would be no fatalities from acute radiation exposure as a result of the release of radioactive material from any of the hypothetical accidents. The radiological risk associated with an accident is maximized on the Granger, Wyoming route, but is not expected to exceed 2.37×10^{-3} LCFs over the 20-year campaign.

For the outbound shipment of SNF to a permanent repository, Table D.12 presents the risk to the crew and the public. The SNF in the sealed canisters is assumed to be cooled at least an average of 20 years and be shipped in the same canister as delivered to the PFSF. The external dose rate is assumed to be reduced by about a factor of two, i.e., to 0.065 mSv/hr (6.5 mrem/hr) at 1 m (3 ft) from the surface of the cask. Over a 20-year period of emptying the PFSF, the greatest risk is to the rail crew who would be subjected to a risk of 1.74×10^{-3} LCFs.

The maximally exposed individual who witnesses the movement of each of the 50 trains per year, each carrying four casks, at a distance of 30 m (98 ft) from each passing train (a very conservative assumption), would receive 0.0011 mSv (0.11 mrem) (see Table D.6), which is about 0.03 percent of the 3.0 mSv (300-mrem) average annual effective dose received from natural background radiation sources. If the MEI witnessed the movement of casks over the entire 20-year campaign, that individual would not receive a dose in excess of 0.022 mSv (2.2 mrem).

D.4 Regional Transportation Risks Near the Alternate Site for the Facility in Fremont County, Wyoming

An alternative site for the proposed facility near Shoshoni, Wyoming, was also examined for this study (see Chapter 7 in this DEIS). This site is located approximately 3.2 km (2 miles) from the Burlington Northern Santa Fe (BNSF) Railway mainline that runs through central Wyoming.

Table D.12. Summary of the risks (as measured by latent cancer fatalities) for the shipment of spent nuclear fuel from the proposed PFSF to a permanent repository (as far the Utah-Nevada border)

To Utah-Nevada border from:	Risks (LCFs) from 1 year rail shipments			Risks (LCFs) from 20 years of rail shipments		
	Incident-free risk		Accident risk	Incident-free risk		Accident risk
	Crew	Public	Public	Crew	Public	Public
PFSF	8.72×10^{-5}	4.00×10^{-5}	1.12×10^{-5}	1.74×10^{-3}	8.00×10^{-4}	2.33×10^{-4}

D.4.1 Identification of Routes

The INTERLINE rail routing model was used to examine possible rail access routes to this alternative site. As with the access routes identified for the Skull Valley site in Utah, the actual distances of the routes to the Wyoming site vary [from about 350 km (220 miles) to 400 km (250 miles)] due to the structure of the INTERLINE rail routing network. Four different access routes could be used to service the alternative site in Wyoming. These rail routes are described and illustrated in Appendix C of this DEIS.

D.4.2 Radiological Impacts

A risk analysis similar to that developed for the Skull Valley site (see Section D.3) was carried out for the alternative Wyoming site, and all available rail routes that could be used to transfer SNF shipping casks to the site were identified as described above. The Wyoming site is assumed to receive approximately 200 casks per year (i.e., the same as the Skull Valley site). The efficiency and exposure of the public and train crew will be affected by the number of casks that will be handled by any single train. Although the shipments are expected to average four casks per train into the site, each train can be expected to handle anywhere from one to six casks. Table D.5 presents the radionuclide inventory for the SNF shipments to the Wyoming site.

There are four possible rail routes that could bring SNF to the Wyoming site. As discussed in Appendix C of this DEIS, they include as starting points of Crandall, WY, Gibson, WY, Mitchell, NE, and Mossmain, MT. Similar to the analysis in Section D.3, it was assumed that all 200 shipments each year move along each of the routes that have been identified. This provides a conservative, upper-bound result for the actual exposure of the population along each route. Because each route is expected to carry some shipments, the exposures should be considerably less than the exposures computed along any of the routes shown. The results of the RADTRAN4 computer runs are discussed below. The exposure data are presented in Table D.13.

Table D.14 lists the risk of LCFs for shipments of SNF expected to result from radiation exposure during incident-free transportation and accidents assuming all the shipments come to the Wyoming site on each of the four possible routes. This set of results is conservative, since some shipments will come in to the Wyoming site on each of the routes, thereby reducing the risk computed for any one of the routes specifically examined. Radiation doses to the population and rail crews were converted to estimates of LCFs using the upper limit risk coefficient suggested by the NAS (ICRP 1991; NAS 1990).

Assuming an average of four casks are shipped on each train, this study indicates that the radiological risks of the rail shipments of SNF are quite low. In any year, the number of LCFs statistically expected to occur from the calculated exposures would not exceed 2.34×10^{-4} LCFs for the two person crew or 7.95×10^{-5} LCFs for members of the public exposed during incident-free transportation if all the shipments came through the Mitchell, NE, route. For the entire 20-year campaign, the number of LCFs statistically expected to occur from the calculated exposure data would not exceed 4.67×10^{-3} LCFs for the two-person crew or 1.59×10^{-3} LCFs for members of the public exposed during incident-free transportation if all the shipments came through the Mitchell, NE, route.

Table D.13. Summary of doses for the shipment of spent nuclear fuel to the Wyoming site by rail

	Annual dose, 200 casks per year				20 year life campaign			
To Wyoming ISFSI from:	**Crew dose, [person-Sv (person-rem)]**	**Pop. dose, [person-Sv (person-rem)]**	**MEI, person-[Sv (rem)]**	**Accident pop. dose [person-Sv (person-rem)]**	**Crew dose, [person-Sv (person-rem)]**	**Pop. dose, [person-Sv (person-rem)]**	**MEI, person-[Sv (rem)]**	**Accident pop. dose [person-Sv (person-rem)]**
Crandall, WY	0.00576 (0.576)	0.00146 (0.146)	1.11×10^{-6} (1.11×10^{-4})	7.19×10^{-4} (7.19×10^{-2})	0.115 (11.5)	0.0292 (2.29)	2.22×10^{-5} (2.22×10^{-3})	0.0144 (1.44)
Gibson, WY	0.00578 (0.578)	0.00153 (0.153)	1.11×10^{-6} (1.11×10^{-4})	7.37×10^{-4} (7.37×10^{-2})	0.116 (11.6)	0.0306 (3.06)	2.22×10^{-5} (2.22×10^{-3})	0.0147 (1.47)
Mitchell, NE	0.00584 (0.584)	0.00159 (0.159)	1.11×10^{-6} (1.11×10^{-4})	7.51×10^{-4} (7.51×10^{-2})	0.117 (11.7)	0.0318 (3.18)	2.22×10^{-5} (2.22×10^{-3})	0.0150 (1.50)
Mossmain, MT	0.00578 (0.578)	0.000884 (0.0884)	1.11×10^{-6} (1.11×10^{-4})	2.56×10^{-4} (2.56×10^{-2})	0.116 (11.6)	0.0177 (1.77)	2.22×10^{-5} (2.22×10^{-3})	0.00512 (0.512)

Table D.14. Summary of the cumulative annual and 20-year campaign risks (as measured by latent cancer fatalities) for the shipment of spent nuclear fuel by rail to the alternative Wyoming ISFSI site

To the Wyoming site from:	Risks (LCFs) from 1 year rail shipments			Risks (LCFs) from 20 years of rail shipments		
	Incident-free risk		Accident risk	Incident-free risk		Accident risk
	Crew	Public	Public	Crew	Public	Public
Crandall, WY	2.30×10^{-4}	7.30×10^{-5}	3.60×10^{-5}	4.61×10^{-3}	1.46×10^{-3}	7.20×10^{-4}
Gibson, WY	2.31×10^{-4}	7.65×10^{-5}	3.69×10^{-5}	4.62×10^{-3}	1.53×10^{-3}	7.38×10^{-4}
Mitchell, NE	2.34×10^{-4}	7.95×10^{-5}	3.76×10^{-5}	4.67×10^{-3}	1.59×10^{-3}	7.52×10^{-4}
Mossmain, MT	2.31×10^{-4}	4.42×10^{-5}	1.28×10^{-5}	4.62×10^{-3}	8.84×10^{-4}	2.56×10^{-4}

The results of the analysis indicate that there would be no fatalities from acute radiation exposure as a result of the release of radioactive material from any of the hypothetical accidents. The radiological risk associated with an accident is maximized on the Mitchell, NE route, but is not expected to exceed 3.76×10^{-5} LCFs in any year and 7.52×10^{-4} LCFs over the life of the campaign. The MEI who witnesses the movement of each of the 50 trains per year, each carrying four casks, at a distance of 30 m (98 ft) from the passing train, would receive 0.0011 mSv (0.11 mrem), which is 0.03 percent of the 3.0 mSv (300-mrem) average annual effective dose received from natural background radiation sources. If the MEI witnessed the movement of casks over the entire 20-year campaign, that individual would not receive a dose in excess of 0.022 mSv (2.2 mrem).

D.5 References

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